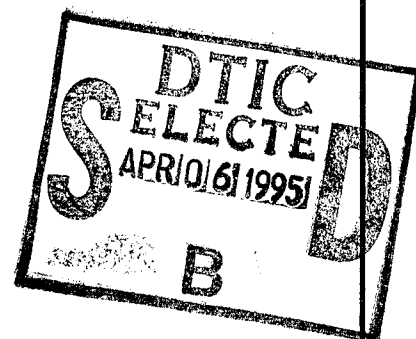


# AOARD REPORT

XV NSO/Sac Peak Solar Workshop held at Sunspot, New Mexico on 19-23 September 1994.

19-23 Sept 1994  
Prof V. Krishan  
Indian Institute of Astrophysics



With financial support provided under the AFOSR sponsored Window-on-Science program, Prof V. Krishan, Indian Institute of Astrophysics, Bangalore, India, presented a paper entitled "A Turbulent Model of the Solar Granulation" at XV NSO/Sac Peak Solar Workshop held in Sunspot, New Mexico on 19-23 September 1994. The report discusses the details of the paper presented by Prof Krishan. The paper dealt with a new model for the development of convective velocity fields at various spatial scales in order to understand the differential rotation of the sun which affects the solar dynamo responsible for the magnetic activity as seen in its myriad forms. The new model is based on inverse cascading of energy to take into account the granulation phenomenon in its entirety.

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Report on my participation in the 15th NSO/Sacramento Peak Workshop,  
Sept. 19-23, 1994, on Infrared Tools for Solar Astrophysics: What's Next?

I presented a paper on 'A Turbulent Model of the Solar Granulation' at the workshop. This is a new model for the development of flows on various different spatial scales. It is extremely important to understand the convective velocity fields as they redistribute angular momentum causing the differential rotation of the sun, which in turn affects the workings of the solar dynamo responsible for the magnetic activity seen in its myriad forms, including coronal mass ejections so important for understanding the Solar-Terrestrial relation and space weather.

We have proposed an Inverse Cascade model of energy in order to account for the granulation phenomenon in its entirety. The inverse cascade of energy is studied using the Kolmogorovic as well as the Navier-Stokes approach. The Kolmogorovic approach predicts a new branch of the energy spectrum which goes as  $E(K) \propto K^{-1}$ . It is very gratifying to report that it agrees fairly well with the observed spectrum of  $K^{-0.7}$ . Encouraged by this maiden success, we have proposed measurements of some physical quantities like the helicity and helicity-helicity correlations and their variations with spatial scales on the solar atmosphere. the proposal is as follows:

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1. That the photospheric motions possess vorticity has been amply demonstrated. Not much attention has been paid to the helical nature of these flows. It will be worthwhile to measure helicity  $H$  defined as:

$$H = \vec{V} \cdot \vec{\omega} \quad \vec{\omega} = \vec{\nabla} \times \vec{V}$$

and check if the helicity increases towards large spatial scales, since the alignment of velocity and vorticity retards the flow of energy to small scales as can be seen from the nonlinear term expressed as:

$$(\vec{V} \cdot \vec{\nabla}) = \frac{1}{2} \nabla (V^2) + \vec{V} \times \vec{\omega}$$

The alignment of  $\vec{V}$  and  $\vec{\omega}$  reduces the  $(\vec{V} \cdot \vec{\nabla})V$  term which is responsible for cascade of energy towards small scales.

2. We should also measure Helicity-Helicity correlation defined as:

$$I = \int H(r)H(r+x)d^3r$$

and check if the correlation length  $x$  increases with height or if  $I$  increases with height.

3. According to the theory of inverse cascade.

$$\frac{I}{E^2} = Lz = \text{Constant, is the largest}$$

dimension of a three dimensional isotropic structure. Here

$$E = \frac{1}{2} V^2 \text{ is the kinetic energy}$$

Structure with dimensions larger than  $Lz$  are anisotropic with horizontal dimensions  
>> vertical dimension.

4. The relationship among flow divergence helicity and vorticity must be studied as:

$$\frac{\delta H}{\delta t} = \vec{\omega} \cdot \vec{\nabla} B - H(\vec{\nabla} \cdot \vec{V}) - \vec{V} \cdot \vec{\nabla} H$$

#### BERNOULLI FUNCTION

$$B = \frac{1}{2} V^2 - \int \frac{dp}{\rho} - \varphi$$

where  $\varphi$  is the gravitational potential,  $p$  the pressure and  $\rho$  is the mass density.

5. Furthermore, jumps in the Bernoulli function are associated with shocks, which may be playing an important role in heating some regions of the solar atmosphere.

I believe that the inclusion of this bit of physics in the interpretation of solar photospheric and chromospheric motions will unfold the workings of the convective processes on the Sun, from which we could investigate convection in other astrophysical situations with more confidence.

In particular, a possible collaboration with the following scientists at SAC PEAK may be set up: Jeff Kuhn, Larry November, G.Simon and Stephen Keil.

I also foresee a collaboration with S.Koutchmy of the Institute d'Astrophysique de Paris, CNRS 98 bis Bld Arago, 75014, Paris and T.Roudier of Univ. Paul Sabatier, Obs. de Pic du Midi, 9 rue du Pont de la Moulette, 65200 Bagnères de Bigorre, France, on the interpretation of their observations on Solar Granulation and coronal structures. More specifically, S.Koutchmy's recent observations of small scale toroidal vortex structure travelling in the solar corona, can be interpreted and modelled by using some of the concepts outlined above, for example the role of helicity and Bernoulli function in the formation and stability of these structures.

The last but not least, we believe that the knowledge, experience and wisdom attained by studying the solar processes will go a long way in understanding the solar-terrestrial relation on the one hand and solar-astrophysical connection on the other. I enjoyed attending this workshop and thank you for making it possible.

VINOD KRISHAN

*Vinod Krishan*